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(54) **Flux formulation**

Flussmittelzusammensetzung

Composition de flux

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(73) Proprietor: **Ford Motor Company**
Dearborn, MI 48126 (US)

(72) Inventors:
• **Nation, Brenda Joyce**
Troy, Michigan 48098 (US)
• **Adams, Karen Marie**
Dearborn Heights, Michigan 48125 (US)

• **Gao, Guilian**
Novi, Michigan 48375 (US)
• **Baker, Jay DeAvis**
Dearborn, Michigan 48121 (US)

(74) Representative: **Messulam, Alec Moses**
A. Messulam & Co. Ltd.,
43-45 High Road
Bushey Heat, Herts WD2 1EE (GB)

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DescriptionField of the invention

5 **[0001]** The invention relates to a flux formulation for use in the assembly of electronic circuit boards.

Background of the invention

10 **[0002]** In the electronics industry, solders are used for assembling electronic circuit boards. To function effectively, solder must wet the substrate with a strong, permanent bond to be formed. Often, a flux is used to enhance the task of wetting the substrate. The ability to remove the surface oxide films from the substrate is another desirable characteristic of a flux. The constituents of most fluxes are therefore often both corrosive and ionically conductive.

15 **[0003]** Solder joints form interconnections between various levels of an electronic package. These joints are made between solderable metallized surfaces, such as Cu, Cu plated with Pb-Sn, Ni, or Ni plated with Au. The metallized layers are typically heavily contaminated with metal oxides, carbon compounds, and other materials due to extended exposure in the manufacturing environment. A metal surface contaminated by these materials cannot be wet by solder. However, once this surface contamination is removed, the solder wets the metallization and forms a metallurgically sound solder joint, which will both hold the various electronic components in place and pass electrical signals.

20 **[0004]** Historically, oxides have been removed from metallized surfaces using solder processes by the application of liquid fluxes. Flux (from the latin term meaning "to flow") is applied to a surface to assist in wetting by the solder. Conventionally, a flux consists of active agents dissolved or dispensed in a liquid carrier. The carrier for flux is typically alcohol-based, with varying concentrations of acids or salts as activators. The function of the activators is to reduce base metal oxides. The activators most commonly used in fluxes are: abietic acid (also present in rosin), adipic acid, and amine salts.

25 **[0005]** The purpose of a flux is to:

- (1) remove the oxide from the metallization;
- (2) remove the oxide on the molten solder to reduce the surface tension and enhance flow;
- (3) inhibit subsequent oxidation of the clean metal surfaces during soldering; and
- 30 (4) assist in the transfer of heat to the joint during soldering.

35 **[0006]** After a solder joint is formed, a flux residue remains. The residue consists of a carrier, such as rosin or resin that is not evaporated, acid or salt deposits, and the removed oxides. The residue can be deleterious to the long-term reliability of an electronic package if it is not removed. The resin can absorb water and become an ionic conductor which could result in electrical shorting and corrosion. The residual activator can, over a period of time, corrode the soldered components and cause electrical opens. Furthermore, the flux residue, which still covers the entire assembly, is present not only on the surface, but also underneath the components where inspection is difficult and the residue is hard to remove.

[0007] The current practice is either to select a no-clean flux or use post-soldering cleaning to remove the flux residue.

40 **[0008]** The use of fluxes which leave a benign flux residue can avoid cleaning after soldering. However, most of the no-clean fluxes currently available contain a very high percentage of volatile organic compounds (VOCs), such as isopropanol, which are emitted to the environment during the soldering process. VOCs are harmful to the environment and are regulated by the EPA and many states.

45 **[0009]** If fluxes which leave corrosive and/or hygroscopic residues are used, post soldering cleaning using chlorinated fluorocarbons (CFCs), organic solvents, semi-aqueous solutions, or water is required. For this type of process, in addition to VOC emissions from the soldering process, the cleaning process results in emission of CFCs and waste water. All add to environmental pollution and production costs.

[0010] It is known that microorganisms (microbes, e.g. bacterial, fungi, and molds) may grow in aqueous-based fluxes. The microbes most likely are spawned from inadvertent contamination by sources in the environment: dust and dirt particles, for example, carry common soil bacteria.

50 **[0011]** Microbial contamination and fluxes could, under some circumstances, adversely affect the soldering process. For example, microbial growth consumes adipic acid, converting it to a biomass, CO₂, and possibly partially oxidized products of adipic acid. Accordingly, there is a concern that solderability could be inhibited by contaminated flux forming a coating of biomass or biomaterials such as protein before contact with a solder wave. Additionally, post-solder microbial residues could affect electrical reliability and conformal coat adhesion. Further, microbial consumption of adipic acid could deactivate the flux.

55 **[0012]** One approach to alleviating this problem is the use of certain biocidal chemicals. However, many such chemicals known today tend to have a very low human exposure limit and result in ionic or halide residues.

[0013] One approach is suggested by U.S. Patent No. 5,085,365. That reference discloses a non-toxic, non-corrosive liquid soldering flux comprising an organic acid and a non-toxic carrier, such as water. The flux requires cleaning after soldering with deionized water, or other solvents, which generates waste requiring disposal. U.S. Patent No. 4,360,392 discloses a solder flux composition having as a solvent a mixture of water and one or more aliphatical alcohols. U.S. Patent No. 2,581,820 discloses the use of distilled water in a soldering flux. U.S. Patent No. 4,994,119 discloses a water-soluble soldering flux containing deionized water as the solvent. U.S. Patent No. 3,925,112 discloses that a bacteriostatic agent may be added to a water-based flux.

[0014] US-A-5334260 discloses a flux formulation for use in the assembly of electronic circuit boards comprising: a solvent such as deionized water, a water soluble weak organic acid such as glutaric, succinic or adipic acids, a halide-free non-ionic surfactant, and a biocidal nonvolatile co-solvent from 1 to 5 wt.%. Though a number of suitable non-ionic surfactants are disclosed, all have a chemical composition which is quite different to the non-ionic surfactant used in the formulation of the invention to be described hereafter.

Object of the invention

[0015] The invention to provide a flux system which emits no or very low VOCs during soldering, leaves a benign residue after soldering and thus does not require post-soldering cleaning. Furthermore, in order to reduce concerns over worker safety, the flux should not be flammable.

Summary of the invention

[0016] According to the present invention we provide a flux formulation for use in the assembly of electronic circuit boards having a conformal coating, the formulation comprising: at least 90% by volume of a solvent, wherein the solvent is predominantly deionized water; a water-soluble weak organic acid which is present in the formulation in up to 5% by weight; between 0.01% by weight and 0.05% by weight of 2,6,8-Trimethyl-4-Nonyloxypolyethyleneoxyethanol; a biocidal co-solvent which is present in the formulation in up to 10% by weight. The formulation has been found to be compatible with the usual conformal coatings provided on an electronic circuit board. Furthermore the formulation is environmentally benign. In this manner, the invention dispenses with post-soldering cleaning steps, and provided a non-VOC or low-VOC, no-clean formulation. Materials and energy associated with cleaning are conserved and pollution plus waste including volatile organic compounds (VOC) emissions, chlorofluorocarbon (CFC) emissions, and waste water treatment are prevented. In regions with strict VOC emission regulations, use of a non-VOC or low VOC no-clean flux may be the only means of compliance.

[0017] It has been found that by using the flux formulation of the present invention, there is no inhibition to curing silicone conformal coatings containing a platinum catalyst which encapsulate the circuit board. This type of coating is very sensitive to flux residues. The flux is also expected to be compatible with other types of coatings which are more tolerant towards flux residues such as UV cured silicone and polyurethane. Any benign flux which remains will not impair the integrity of bonding between the conformal coating and the board assembly.

Best Mode(s) For Carrying Out The Invention

[0018] The flux formulation of the invention includes a solvent, a water-soluble, weak organic acid, a halide-free, non-ionic surfactant, and a biocidal co-solvent. The formulation is compatible with the conformal coating which encapsulates the electronic circuit board. Additionally, the flux formulation is environmentally benign and no post-soldering cleaning steps are needed.

[0019] The disclosed soldering flux is used for soldering lead/tin solders to lead/tin or copper metals for printed circuit boards, although the disclosed formulation may be suitable for other applications.

[0020] The solvent comprises mostly deionized water. Other suitable solvents include alcohol and ether. Preferably, the organic acid comprises adipic acid $\text{HOOC}(\text{CH}_2)_4\text{COOH}$. Other organic acids may be used. They include maleic acid, succinic acid, and glutaric acid.

[0021] The surfactant comprises Tergitol TMN-6 (90% aqueous), which is available from Union Carbide Corporation. Its general structural formula is $\text{C}_{12}\text{H}_{25}\text{O}(\text{CH}_2\text{CH}_2\text{O})_n\text{H}$. As the example to be described below confirms, this surfactant is one of the most effective non-ionic wetting agent and penetrant available. It has good solvency and grease-cutting ability. The surfactant is hygroscopic. Accordingly, the conformal coating serves to protect the electronic circuit board from damage caused by absorption of moisture.

[0022] Preferably, the co-solvent comprises an aliphatic alcohol, such as isopropanol. Other suitable co-solvents include ethanol, butanol, and pentanol.

[0023] To meet the desirable objective of leaving no corrosive residues, the disclosed flux formulation uses relatively low concentration and benign active agents.

[0024] It has been found that the specific surfactant selected in the proportion ranges disclosed tends to lower surface tension so that water may wet an underlying circuit board. If more than the disclosed proportions are used, a residue remains which if not washed away may produce deleterious effects over time. For example, residues may be hygroscopic and promote electromigration.

[0025] It is contemplated that the flux formulation of the present invention may, because of its benign character, be allowed to remain on the printed circuit board. Because the flux may be allowed to remain on the board, cleaning steps are also ameliorated. Related expenses, and waste disposal problems are thereby avoided.

[0026] To test electronic reliability and compatibility of fluxes with conformal coatings, a biased pressure cooker procedure was used. The purpose of testing was to ensure product reliability in the harsh environment to which automotive electronics are exposed. An experimental procedure used interdigitated test patterns. Fluxes were sprayed onto a test pattern and heat treated to simulate an actual soldering heat profile. A conformal coating was then applied on top of the flux residue and cured. After curing, the test patterns were subjected to a high temperature and high humidity environment inside a pressure cooker for a given period. A voltage bias was applied between the interdigitated fingers to promote electromigration and dendritic growth. Test patterns were then measured electrically to determine the number of patterns shorted by metallic dendrites formed during the accelerated test. If any short was detected, the flux and the conformal coating were considered as not compatible.

[0027] In the experiments to be described below, the conformal coating was a silicone coating. It is a heat-cured material which contains a platinum catalyst.

[0028] The various formulations listed below of water-based, no-clean fluxes were tested for compatibility with the conformal coating:

TABLE I

Activator (wt%)	Solvents (vol%)	Surfactant	Compatible?
1% malonic acid	25% IPA, 75% DI water	None	No
1% adipic acid	15% IPA, 85% DI water	None	No
1% adipic acid	30% IPA, 70% DI water	None	No
1% adipic acid	50% IPA, 50% DI water	None	No
0.75% adipic acid	15% IPA, 85% DI water	None	No
0.5% adipic acid	15% IPA, 85% DI water	None	No
0.5% adipic acid 0.5% pimelic acid	15% IPA, 85% DI water	None	No
1% adipic acid	DI water	None DF-16	No
1% adipic acid	DI water	0.02% Triton DF-16	No
1% adipic acid	DI water	0.05% Triton DF-16	No
1% adipic acid	10% IPA, 90% DI water	0.02% Triton TMN-6	No
1% adipic acid	5% IPA, 95% DI water	0.01% Tergitol TMN-6	No
1% adipic acid	5% IPA, 95% DI water	0.05% Tergitol TMN-6	No
1% adipic acid	5% IPA, 95% DI water	0.02% Tergitol TMN-6	Yes

[0029] As the above results show, the only formulation which passed the stringent compatibility tests was that which contains 1% adipic acid; 95% (vol.) deionized water; 5% (vol.) isopropanol; and 0.02% Tergitol TMN-6. Tergitol TMN-6 is available from Union Carbide. Its chemical family is alcohol ethoxylates. Its chemical name is 2,6,8-Trimethyl-4-Nonyloxypolyethyleneoxyethanol. The isopropyl alcohol is also known as isopropanol, true-propanol, SEC-propyl alcohol, dimethyl carbinol, isohol, petrohol.

[0030] Using the disclosed flux formulations, a solderability test was conducted by soldering current electronic engine control modules assembled through wave soldering. The flux was sprayed using the production system currently used. The modules were soldered with the current production heat profile in an inert gas wave soldering machine manufactured by Electrovert. Solder joint quality was examined using an optical microscope and compared to soldered joints produced with current production no-clean fluxes. The results indicated that solderability of the water-based flux is comparable to the current production no-clean flux formulation.

[0031] In light of the above-noted disclosure, it will be apparent that the disclosed flux formulation is a non-VOC or

low-VOC rosin/resin-free, no-clean flux. It is water based. It contains no volatile low boiling point solvents, and can optionally contain less than 10% VOC with a biocidal effect, such as IPA thereby eliminating the VOC emission issue. The disclosed formulation has no flammability.

[0032] All percentages or proportions set forth herein are by weight, unless specifically indicated otherwise.

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Claims

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1. A flux formulation for use in the assembly of electronic circuit boards having a conformal coating, the formulation comprising:

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at least 90% by volume of a solvent, wherein the solvent is predominantly deionized water;
a water-soluble weak organic acid which is present in the formulation in up to 5% by weight;
between 0.01% by weight and 0.05% by weight of 2,6,8-Trimethyl-4-Nonyloxypolyethyleneoxyethanol;
a biocidal co-solvent which is present in the formulation in up to 10% by weight.

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2. A flux formulation as claimed in claim 1 wherein the weak organic acid is adipic acid.

3. A flux formulation as claimed in claim 2 wherein 1% by weight of adipic acid is present in the formulation.

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4. A flux formulation as claimed in any one of the preceding claims wherein the biocidal co-solvent comprises isopropanol.

5. A flux formulation as claimed in claim 4 wherein 5% by volume of isopropanol is present in the formulation.

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6. A method for use in the assembly of electronic circuit boards by the soldering of components together comprising heating the components to a desired soldering temperature and applying to the surfaces of the heated components a solder and a flux having the formulation as claimed in any one of the preceding claims.

Patentansprüche

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1. Eine Fließmittel-Formulierung zur Verwendung bei der Montage elektronischer Schaltkarten die eine konforme Beschichtung besitzen, wobei die Formulierung umfaßt:

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mindestens 90 Volumenprozent eines Lösemittels, worin das Lösemittel überwiegend deionisiertes Wasser ist;
eine wasserlösliche, schwache, organische Säure, welche in der Formulierung mit bis zu 5 Gewichtsprozent vorliegt;
zwischen 0.01 Gewichtsprozent und 0.05 Gewichtsprozent 2,6,8-Trimethyl-4-Nonyloxypolyethylen-Oxyethanol; und
ein biozidisches Co-Lösemittel, welches in der Formulierung mit bis zu 10 Gewichtsprozent vorliegt.

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2. Eine Fließmittel-Formulierung nach Anspruch 1, in der die schwache, organische Säure Adipinsäure ist.

3. Eine Fließmittel-Formulierung nach Anspruch 2, wobei in der Formulierung 1 Gewichtsprozent Adipinsäure vorliegt.

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4. Eine Fließmittel-Formulierung nach einem der vorstehenden Ansprüche, in der das biozide Co-Lösemittel Isopropanol umfaßt.

5. Eine Fließmittel-Formulierung nach Anspruch 4, wobei in der Formulierung 5% Volumenprozent Isopropanol vorliegt.

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6. Ein Verfahren zur Verwendung in der Montage elektronischer Schaltkarten durch Zusammenlöten der Bauteile, welches das Erhitzen der Bauteile auf eine gewünschte Löttemperatur und das Aufbringen eines Lotes und eines Fließmittels - welches die Formulierung nach einem der vorstehenden Ansprüche aufweist - auf die Oberflächen der erhitzten Bauteile umfaßt.

Revendications

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1. Formulation de flux destinée à être utilisée au cours de l'assemblage de cartes de circuits électroniques comportant un revêtement qui en épouse les formes, la formulation comprenant :

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au moins 90 % en volume d'un solvant, dans lequel le solvant est de façon prédominante de l'eau désionisée, un acide organique faible soluble dans l'eau qui est présent dans la formulation jusqu'à 5 % en poids, entre 0,01 % en poids et 0,05 % en poids de 2,6,8-triméthyl-4-nonyloxy polyéthylèneoxyéthanol, un co-solvant biocide qui est présent dans la formulation jusqu'à 10 % en poids.

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2. Formulation de flux selon la revendication 1, dans laquelle l'acide organique faible est l'acide adipique.

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3. Formulation de flux selon la revendication 2, dans laquelle 1 % en poids d'acide adipique est présent dans la formulation.

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4. Formulation de flux selon l'une quelconque des revendications précédentes, dans laquelle le co-solvant biocide comprend l'isopropanol.

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5. Formulation de flux selon la revendication 4 dans laquelle 5 % en volume d'isopropanol sont présents dans la formulation.

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6. Procédé destiné à une utilisation au cours de l'assemblage de cartes de circuits électroniques par la soudure des composants ensemble, comprenant le chauffage des composants jusqu'à une température de soudage désirée et l'application sur les surfaces des composants chauffés d'une soudure et d'un flux présentant la formulation selon l'une quelconque des revendications précédentes.
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